Proceedings from the 6th Annual Nutrient Management Conference

Modeling the cost-effectiveness of practices to reduce watershed nitrogen and phosphorus loads

WILLIAM F. LAZARUS
UNIVERSITY OF MINNESOTA

NITROGEN: MINNESOTA'S GRAND CHALLENGE AND COMPELLING OPPORTUNITY
ALEXANDRIA, MINNESOTA
FEBRUARY 18, 2020

Watershed N & P Reduction Decision Tool (NP-BMP.xlsm) Project Team

David J. Mulla
Department of Soil, Water, and Climate
University of Minnesota

Dave Wall
Minnesota Pollution Control Agency

William F. Lazarus
Department of Applied Economics
University of Minnesota

Watershed N & P Reduction Decision Tool (NP-BMP.xlsm)

- Excel spreadsheet linked to soils, landscapes, cropping systems, management practices and crop enterprise budgets
- N & P reductions based on BMP-specific research
- Mainly for watershed planners, not for farm-scale analysis

Versions

- Current version developed in 2011-13, available at https://z.umn.edu/nbmpdoc
- Update is under discussion as part of the MPCA nutrient strategy five-year update
- Work has started on updating the N fertilizer target rate and cover crop BMPs
- Irrigated crops are not modelled separately in the current version

What is the NP-BMP Watershed Nitrogen and Phosphorus Reduction Planning Tool useful for?

- Better assessing which BMPs to focus on – based on both cost and reduction potential/effectiveness
- Understanding the adoption rates needed to achieve major reduction goals - multiple BMPs will most likely be needed
- Understanding farmer costs
- Starting point for developing watershed scenarios using more sophisticated tools

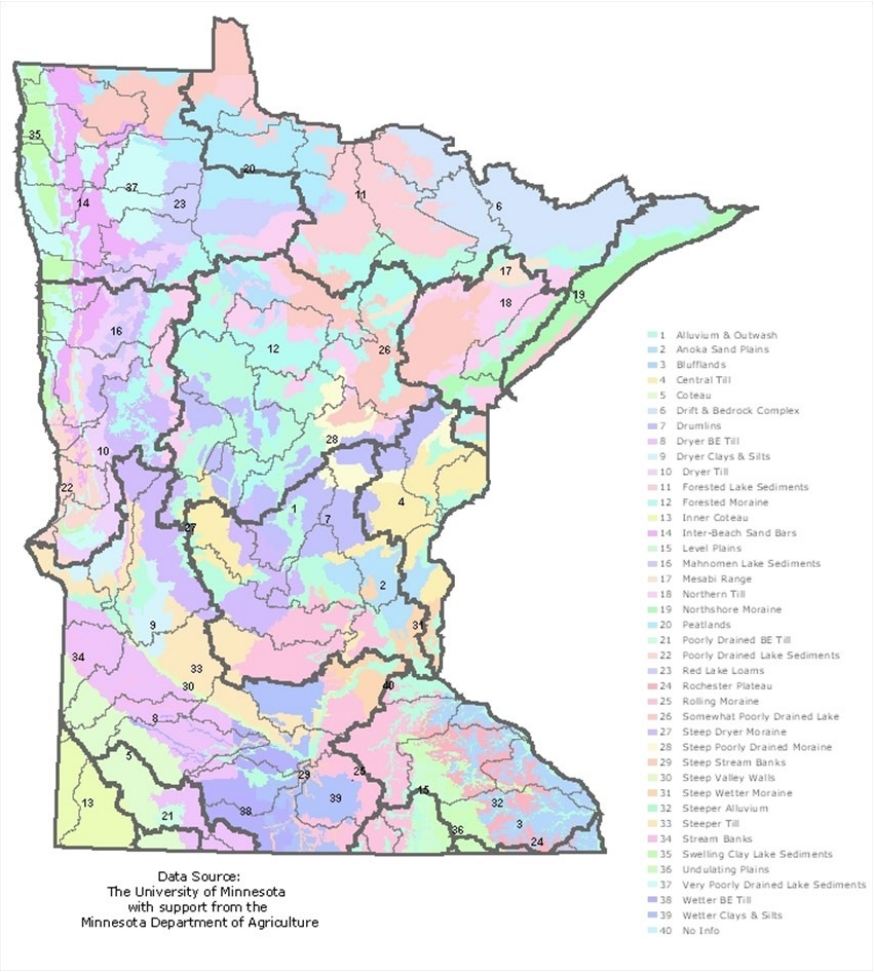
N Reduction Decision Tool BMPs

- Rate and timing of N fertilizer
- Controlled drainage
- Bioreactors
- Saturated buffers
- Planting cover crops
- Planting perennial grass on MARGINAL land
- Installing riparian buffer strips
- Installing or restoring wetlands

- Effects of individual BMPs as well as combinations of BMPs can be evaluated

Agroecoregion-Based N & P Inputs

- N transformations in soil (mineralization, denitrification) and N losses (volatilization, leaching, drainage, etc) are based on soil and landscape factors (represented by agroecoregions)
- County statistics are available for crops and fertilizer sales
- Point data are available for livestock numbers (for manure)
- Approach - estimate N & P inputs and outputs for agroecoregions, then transform results back to watersheds



Agroecoregion results are converted to HUC8 or HUC10 for display

Example:

- Le Sueur River HUC8 watershed – 563,250 acres
- Agroecoregions in the watershed:
  - Wetter clays & silts – 56%
  - Rolling moraine – 42%
  - Steep stream banks – 2%

Suitable acres for BMPs

- Fertilizer rate reductions are only possible in areas where existing application rates exceed University recommendations
- Controlled drainage and bioreactors can be installed on tile drained land with slopes of 0.5%, 1% or 2%
- Perennial grass can be planted on ag land with crop productivity ratings of 60% or less (marginal land)
- Riparian buffers can be installed on ag land within a specified distance from waterways or public ditches
- Wetlands can be restored on tile drained land with hydric soils and high Compound Topographic Index values

Suitable Acres & Default Adoption Rates

Watershed: Statewide

HUC10 Subwatershed: All

19.6 million acres in watershed or state

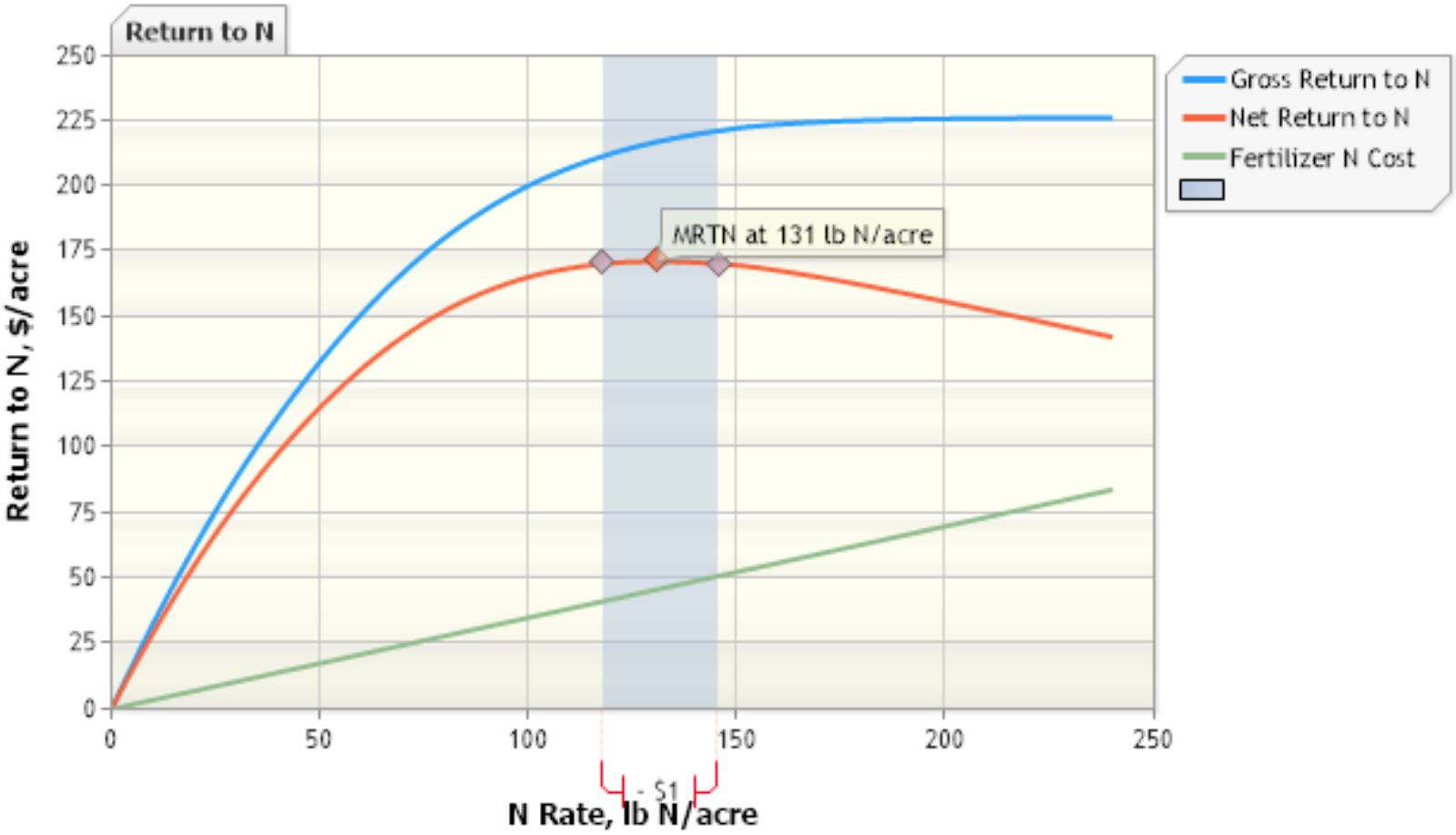
	% suitable	% adoption
Corn acres receiving target N rate, no inhibitor or timing shift	39.64%	80%
Fall N target rate acres receiving N inhibitor	11.68%	40%
Fall N applications switched to spring, % of fall-app. acres	11.68%	40%
Fall N switch to split spring/sidedressing, % of fall acres	11.68%	40%
Restored wetlands	8.14%	20%
Tile line bioreactors	10.16%	5%
Controlled drainage	10.16%	20%
Saturated buffers	10.16%	5%
Alternative tile intakes	5.20%	80%
Riparian buffers	1.62%	0%
Corn grain & soybean acres w/cereal rye cover crop	74.80%	20%
Short season crops planted to a rye cover crop	14.13%	50%
Perennial crop % of marginal corn & soy land > 2% slope	8.36%	30%

Economic Concepts and Assumptions Underlying the Analysis

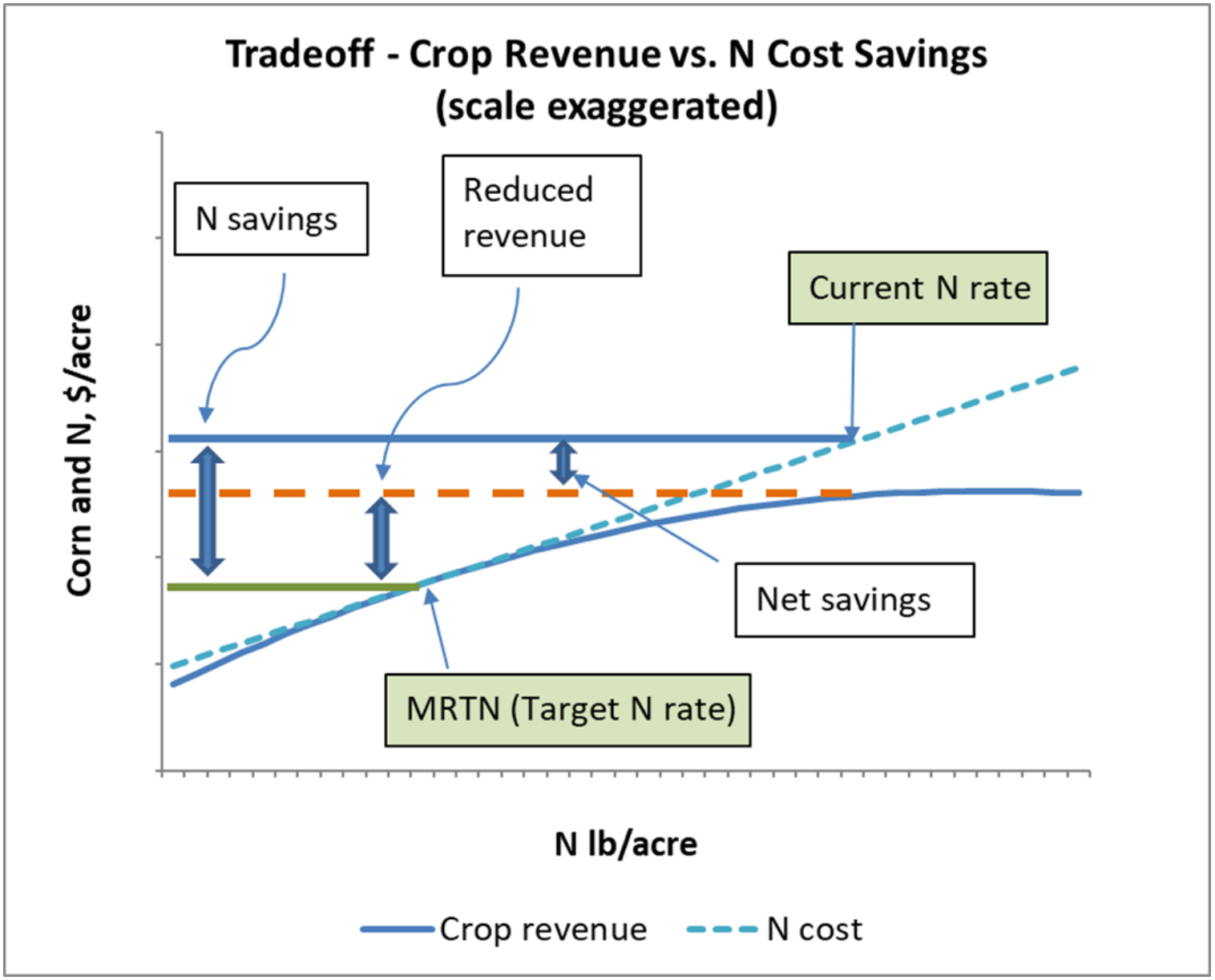
- Effectiveness vs. cost at user-specified adoption rates
- Wet-average-dry weather scenarios allow some consideration of weather risk.
- Will suggest adoption rates that minimize cost for a desired reduction, or vice versa.

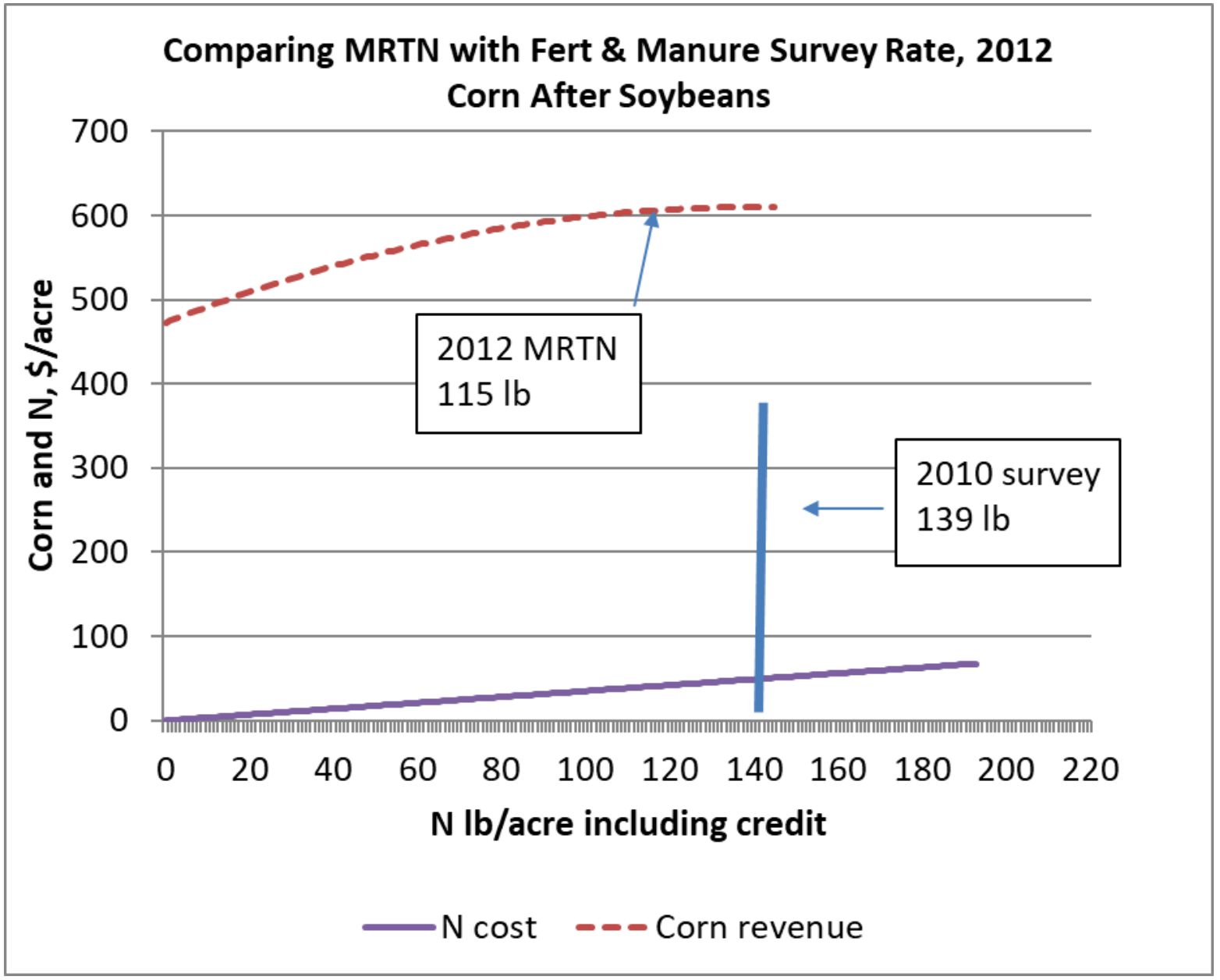
N rate BMPs - considerations

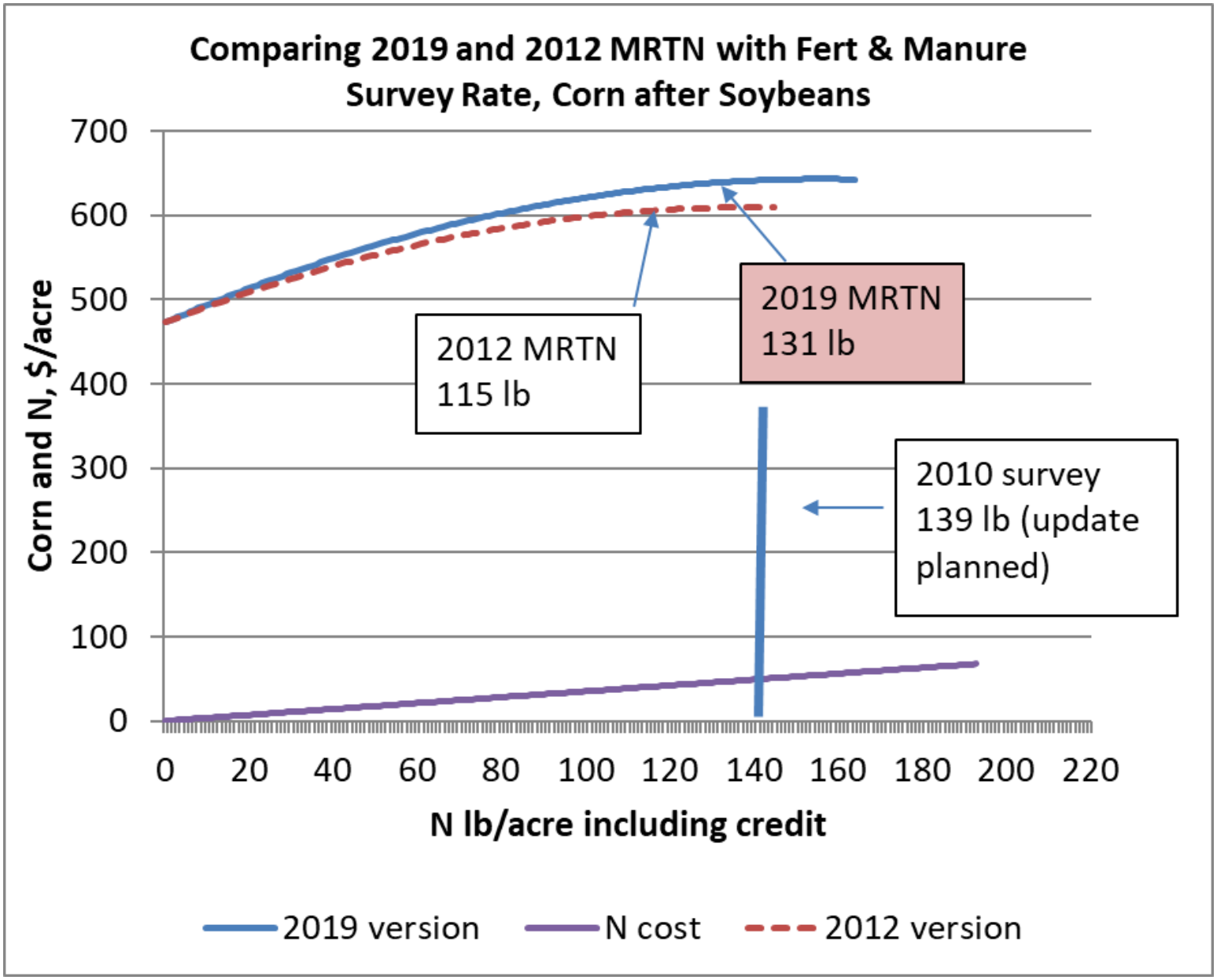
- MDA surveys of fertilizer rates, and manure N
- Legume credits
- Model terminology – “target” rates, not necessarily MRTNs
- N product price differences and application timing affect target rates
- N inhibitor use



Max Return to N (MRTN) point in the Corn Nitrogen Rate Calculator


Tradeoff - Crop Revenue vs. N Cost Savings
(scale exaggerated)
N savings
Reduced revenue
Current N rate
Net savings
MRTN (Target N rate)
Corn and N, $/acre
N lb/acre
Crop revenue
N cost


Comparing MRTN with Fert & Manure Survey Rate, 2012
Corn After Soybeans
Corn and N, $/acre
700
600
500
400
300
200
100
0
0
20
40
60
80
100
120
140
160
180
200
220
N lb/acre including credit
2012 MRTN
115 lb
2010 survey
139 lb
N cost
Corn revenue


Comparing 2019 and 2012 MRTN with Fert & Manure Survey Rate, Corn after Soybeans
Corn and N, $/acre
700
600
500
400
300
200
100
0
0 20 40 60 80 100 120 140 160 180 200 220
N lb/acre including credit
2012 MRTN 115 lb
2019 MRTN 131 lb
2010 survey 139 lb (update planned)
2019 version
N cost
2012 version

Shifting from fall application to spring preplant or sidedressing

Assumed application timing by N product	C/N price ratio	Impact on MRTN, lb/A
NH3 - fall	0.0857	MRTN – 135 lb
Urea – spring preplant	0.1000	-5 lb
UAN - sidedress	0.1143	-10 lb

Assume no over-winter losses	-20 lb

Fall NH3 to spring urea, total change in target N rate	-25 lb

Shifting away from fall NH3 – cost considerations

- More applicators needed to cover the fall-applied acres in spring preplant
- Fertilizer storage needed over winter
- A floater for urea would cover more acres/day than an NH3 toolbar
- Split preplant/sidedress requires two sets of applicators
- More weather risk – possible yield loss from delayed planting in wet years

Controlled Drainage and bioreactor BMPs

- Controlled drainage reduces N losses from treated area in tile drainage
- Max of 0.5%, 1% or 2% slopes
- Installation costs & annual repair and maintenance costs are considered
- Bioreactor is assumed to treat 30% of the drainage water.

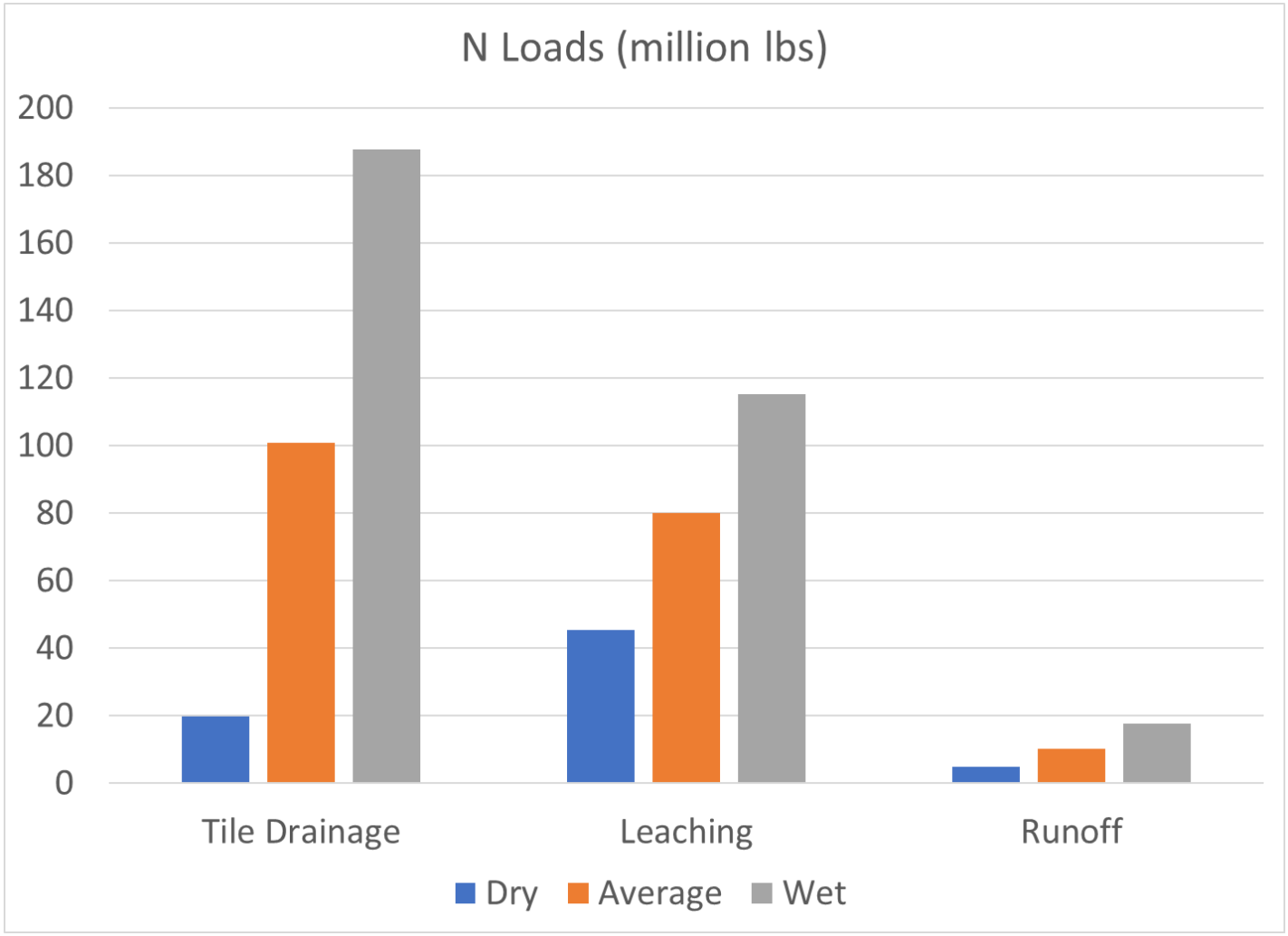
Wetland Restoration BMP

- Assumed to cover 2% of the upland contributing area treated with another 7% in buffers around them.
- Reductions in N loadings from wetlands are assumed to be 50%

Riparian Buffers and Perennial Grass

- N loadings from these are assumed to be negligible.
- They replace annual crops that require higher rates of N fertilizer.

Wet and Dry Weather Scenarios Affect N Loadings (statewide amounts shown)



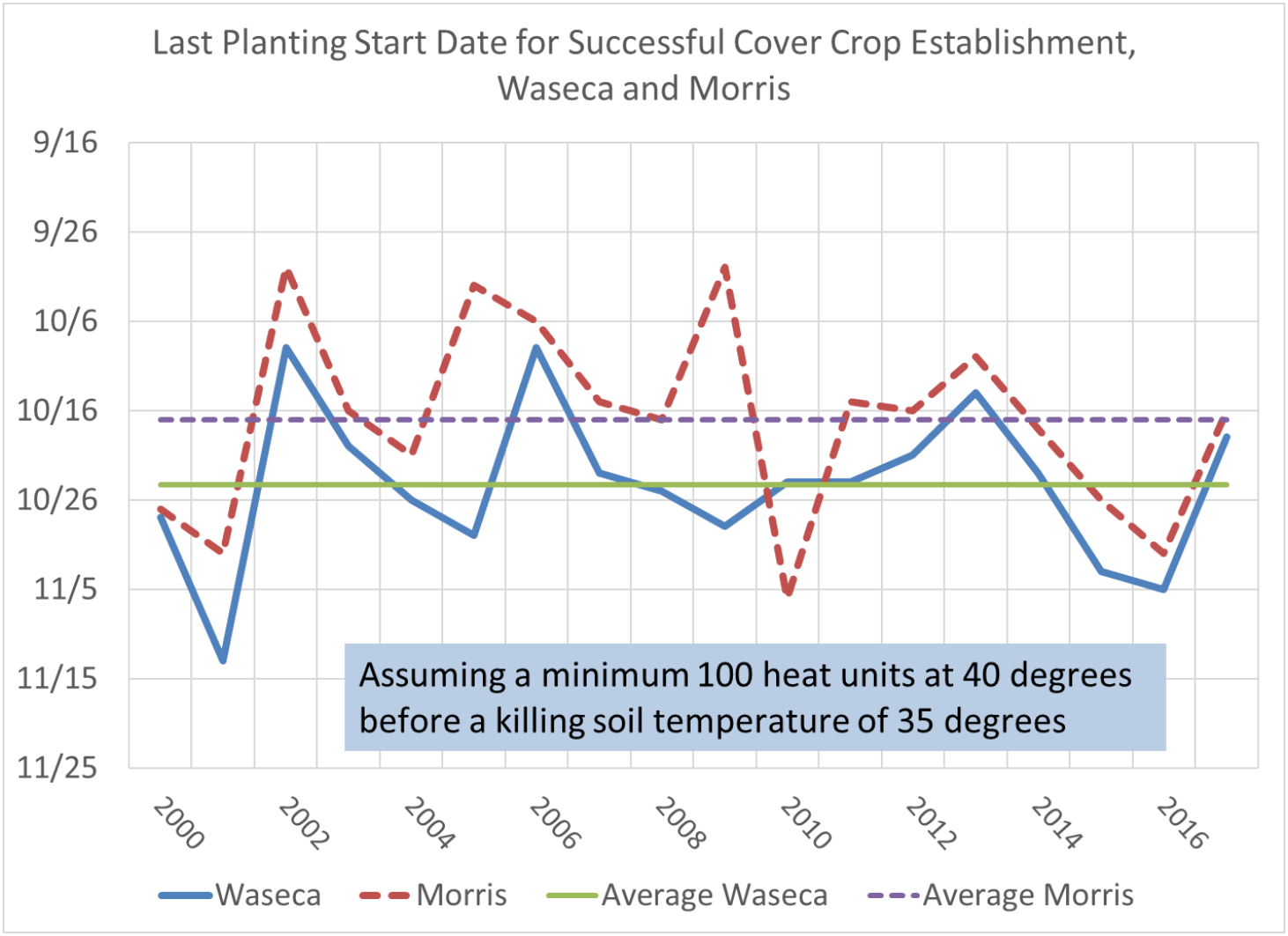
Cover crop BMP

- Following corn grain, soybeans, short-season crops, and sugar beets
- Focus - N scavenging, less tile line N
- Seeding methods –
  - aerial application into standing crop
  - ground equipment after harvest
- Probabilities related to fall weather –
  - CC planting completed
  - Sufficient growth to reduce tile line N

Modeling a “Typical” Cover Crop Scenario

- Seeding rate?
- Price of the seed?
- Seeding completed?
- Seeding successful?
- Reduction in N loading?
- Impact on main crop yields?
- Other benefits or risks?

How Early Would a Cereal Rye Cover Crop Have to be Seeded For Successful Establishment?



How Early Can We Plant a Cover Crop After Soybean or Corn Harvest?

Soybeans & Corn Harvested in MN, 2014-18 Average

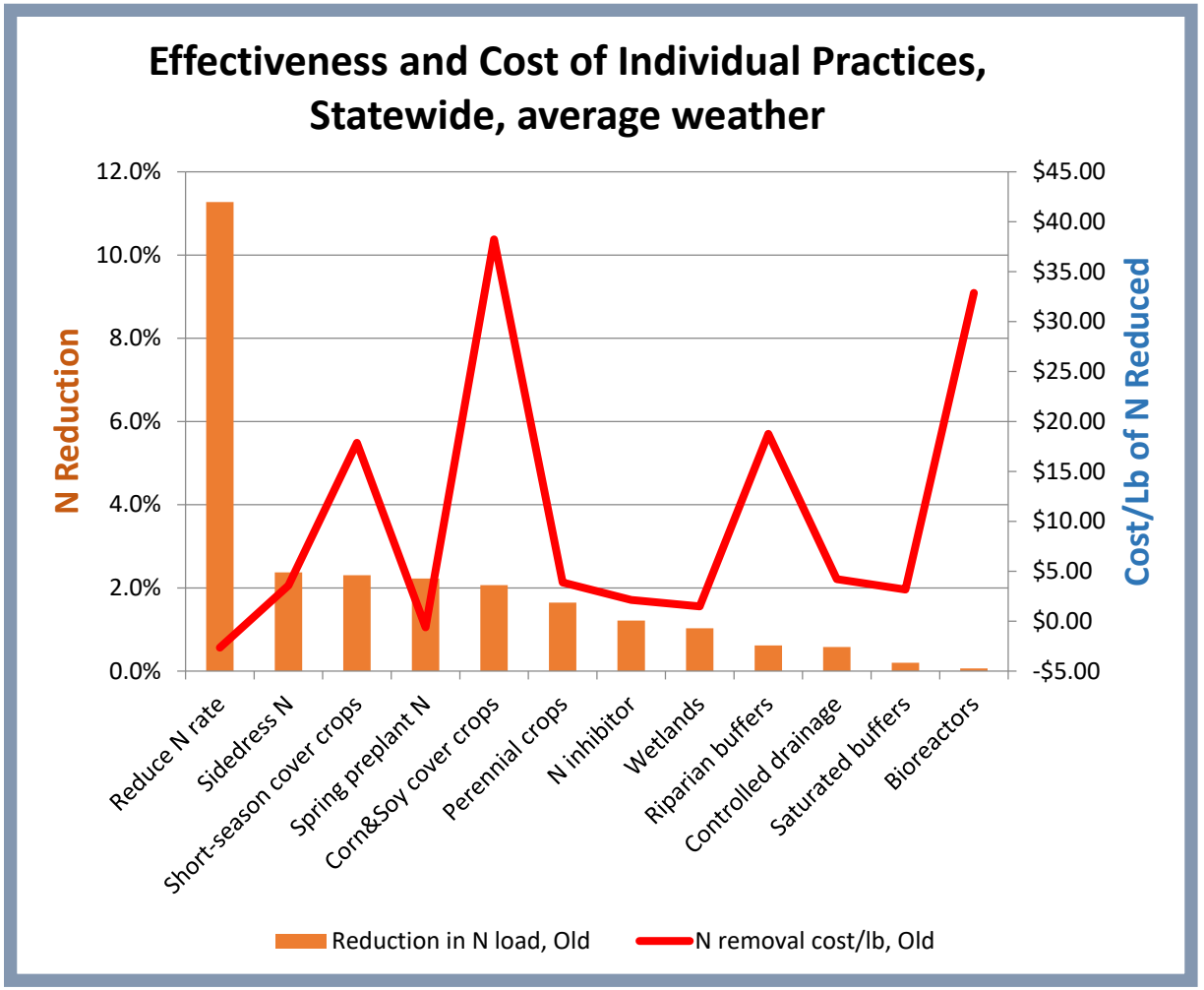
Week ending	Soybeans	Corn grain
October 6	43%	26%
October 13	62	38
October 20	81	35
October 27	93	56
November 3	97	75

Cover crop cost/lb of N removed

Parameters:	Ground Eq, soy to corn	By Air, corn grain to soy	C/S rotation
Seeding & termination, $/A completed	$44	$54	$49
Completion rates	90%	90%	90%
Seeding & termination, $/A overall	$40	$48	$44
Seeding success rates	80%	50%	65%
Seeding & termination, $/A successful	$50	$97	$67
Tile line N reduction when successful	40%	50%	45%
N removed, lb/A	4.2 lb	2.3 lb	3.2 lb
Tile line N reduction overall		33%	
Yield impact on following year's crop	2%	4%	3%
Seeding & term. cost, yield increases & cost savings, $/A overall	$30	$29	$29
Cost/lb of N removed	$7/lb	$13/lb	$9/lb

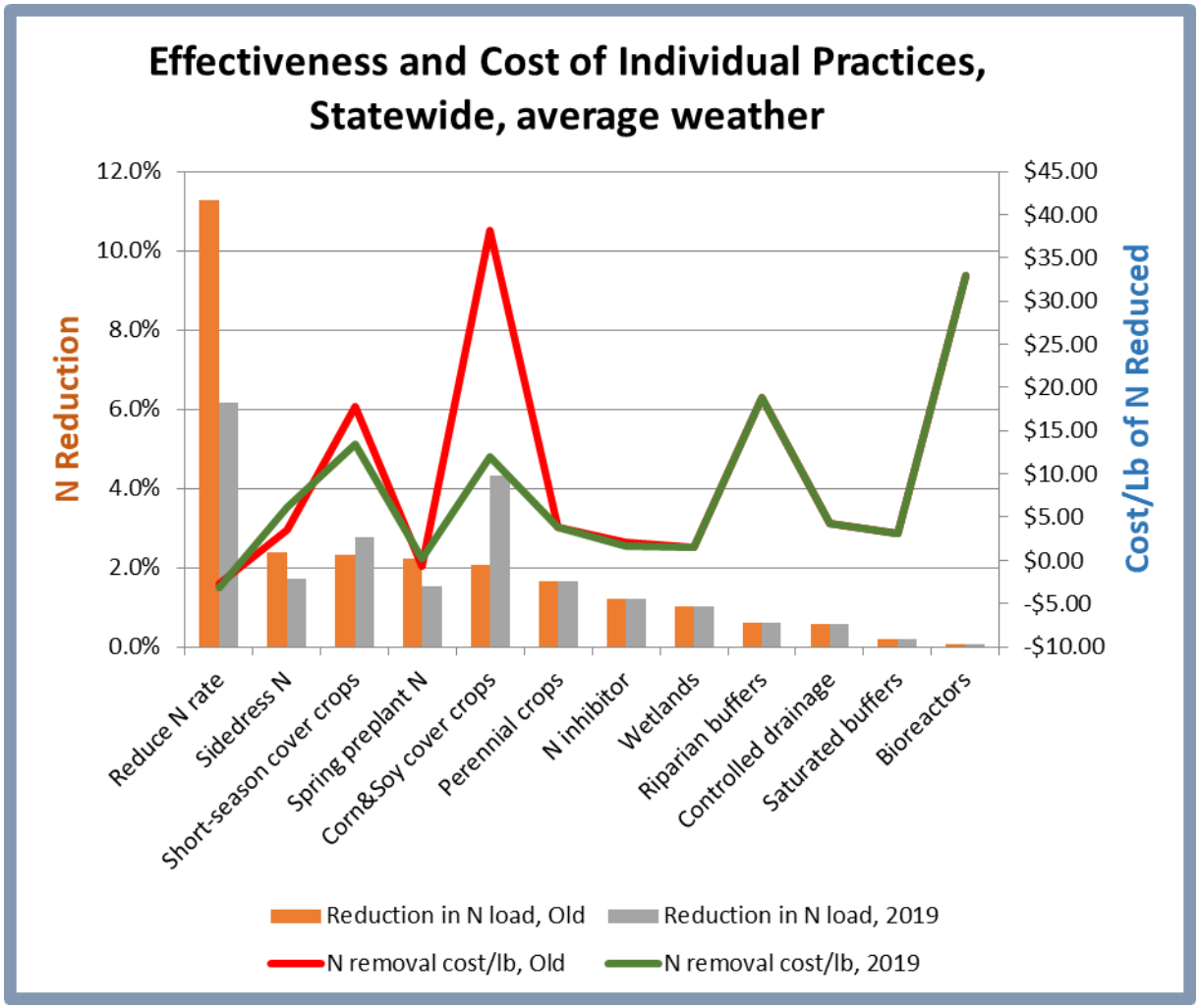
Updates of the cover crop and N rate calculations are in progress.

2012 version:

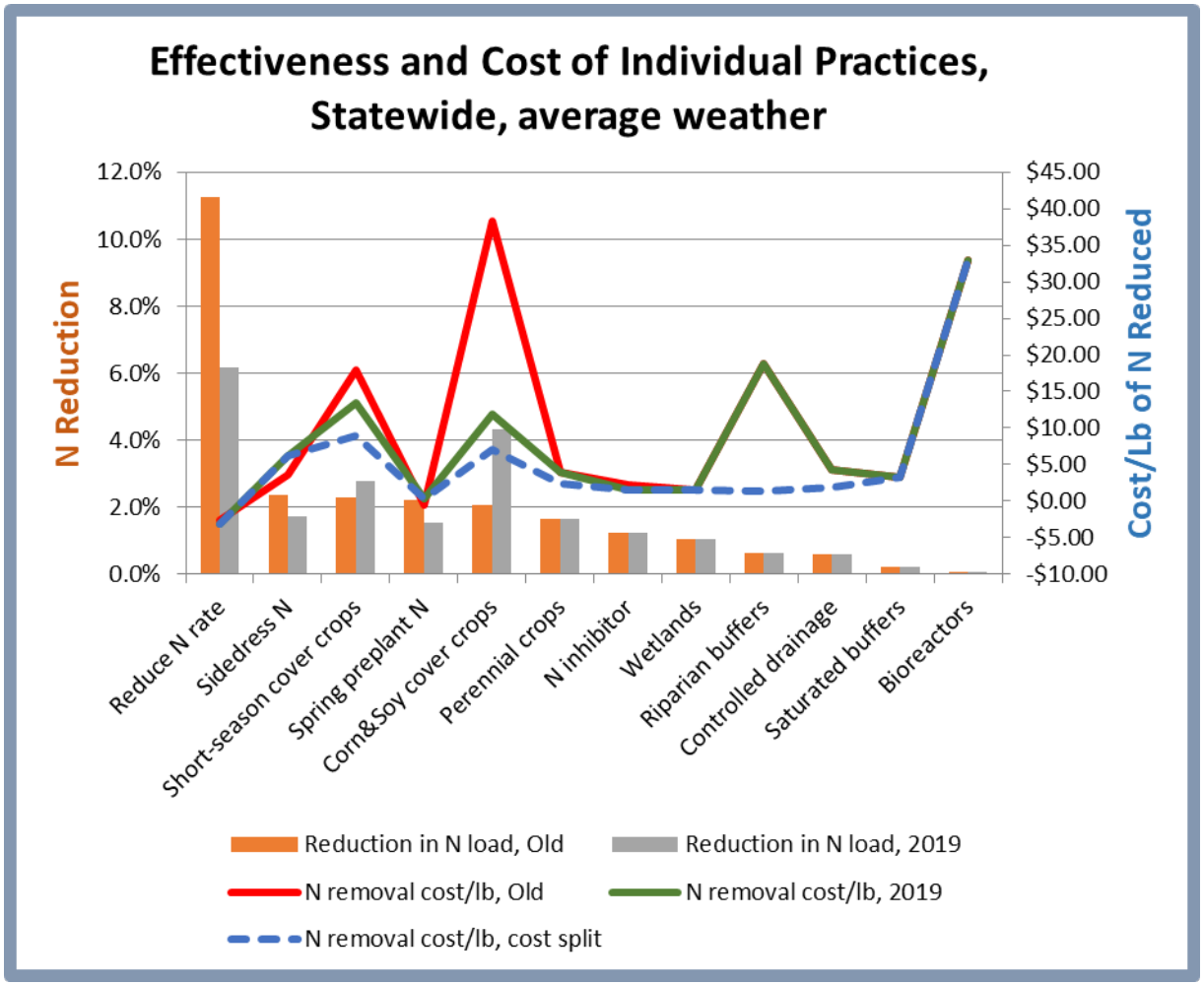


Updates of the cover crop and N rate calculations:

2012 and draft 2020 N rate & cover crop calculations:



Cost/lb of N removed if cost is split 50:50 with P removal (dotted line)



Suitable Acres & Default Adoption Rates, N & P Version

Watershed: Statewide

HUC10 Subwatershed: All

19.6 million acres in watershed or sta

	% existing	% suitable	% adoption
Corn acres receiving target N rate, no inhibitor or timing shift	NA	39.64%	80%
Fall N target rate acres receiving N inhibitor	NA	11.68%	40%
Fall N applications switched to spring, % of fall-app. acres	NA	11.68%	40%
Fall N switch to split spring/sidedressing, % of fall acres	NA	11.68%	40%
Adopt BMP P2O5 rate: Apply U of MN recs	NA	88.93%	80%
Fall corn&wheat P fert to preplant/starter	23.75%	7.70%	50%
Use reduced tillage on corn, soy & small gr >2% slopes	18.50%	31.83%	40%
Restored wetlands	NA	8.14%	20%
Tile line bioreactors	NA	10.16%	5%
Controlled drainage	NA	10.16%	20%
Saturated buffers	NA	10.16%	5%
Alternative tile intakes	1.73%	5.20%	80%
Riparian buffers, perm&intermit streams, 22 avg feet wide	14.30%	0.71%	0%
Corn grain & soybean acres w/cereal rye cover crop	0.00%	74.80%	20%
Short season crops planted to a rye cover crop	0.00%	14.13%	50%
Perennial crop % of corn & soy area	0.00%	8.36%	30%
Inject or incorp manure	0.00%	4.82%	50%

Overall Results – 2012 version

Future scenario – assumes buffers already in place

Cropland N load reduction with these adoption rates:	20.2%	38,596 (000 lb/year)
Cropland P load reduction with these adoption rates:	18.5%	1,301 (000 lb/year)

Treatment cost before fertilizer cost savings & corn yield impacts	$301.92	million/year
N & P fertilizer cost savings & corn yield impacts	-$196.39	
Savings from reduced tillage	-$34.73	
Net BMP treatment cost	$70.81	million/year

Buffers alone, 100% adoption

Cropland N load reduction with these adoption rates:	0.6%	1,179 (000 lb/year)
Cropland P load reduction with these adoption rates:	10.1%	712 (000 lb/year)

Treatment cost before fertilizer cost savings & corn yield impacts	$24.40	million/year
N & P fertilizer cost savings & corn yield impacts	-$2.27	
Savings from reduced tillage	$0.00	
Net BMP treatment cost	$22.13	million/year

Overall Results – 2012 version and possible 2020 updates

2012 version

Cropland N load reduction with these adoption rates:	20.2%	38,596 (000 lb/year)
Cropland P load reduction with these adoption rates:	18.5%	1,301 (000 lb/year)

Treatment cost before fertilizer cost savings & corn yield impacts	$301.92	million/year
N & P fertilizer cost savings & corn yield impacts	-$196.39	
Savings from reduced tillage	-$34.73	
Net BMP treatment cost	$70.81	million/year

2020 w/new MRTN and cover crop update

Cropland N load reduction with these adoption rates:	19.0%	36,358 (000 lb/year)
Cropland P load reduction with these adoption rates:	20.3%	1,430 (000 lb/year)

Treatment cost before fertilizer cost savings & corn yield impacts	$228.10	million/year
N & P fertilizer cost savings & corn yield impacts	-$191.77	
Savings from reduced tillage	-$34.73	
Net BMP treatment cost	$1.60	million/year

Conclusions – N BMP Decision Tool

- Users select a target watershed, climate, and extent of adoption of various N reduction BMPs
- BMPs are limited by suitable acres
- Estimates N and P load reductions for individual practices and combinations
- Approaches to achieving N load reductions greater than 25% are challenging

Thank You. Questions?